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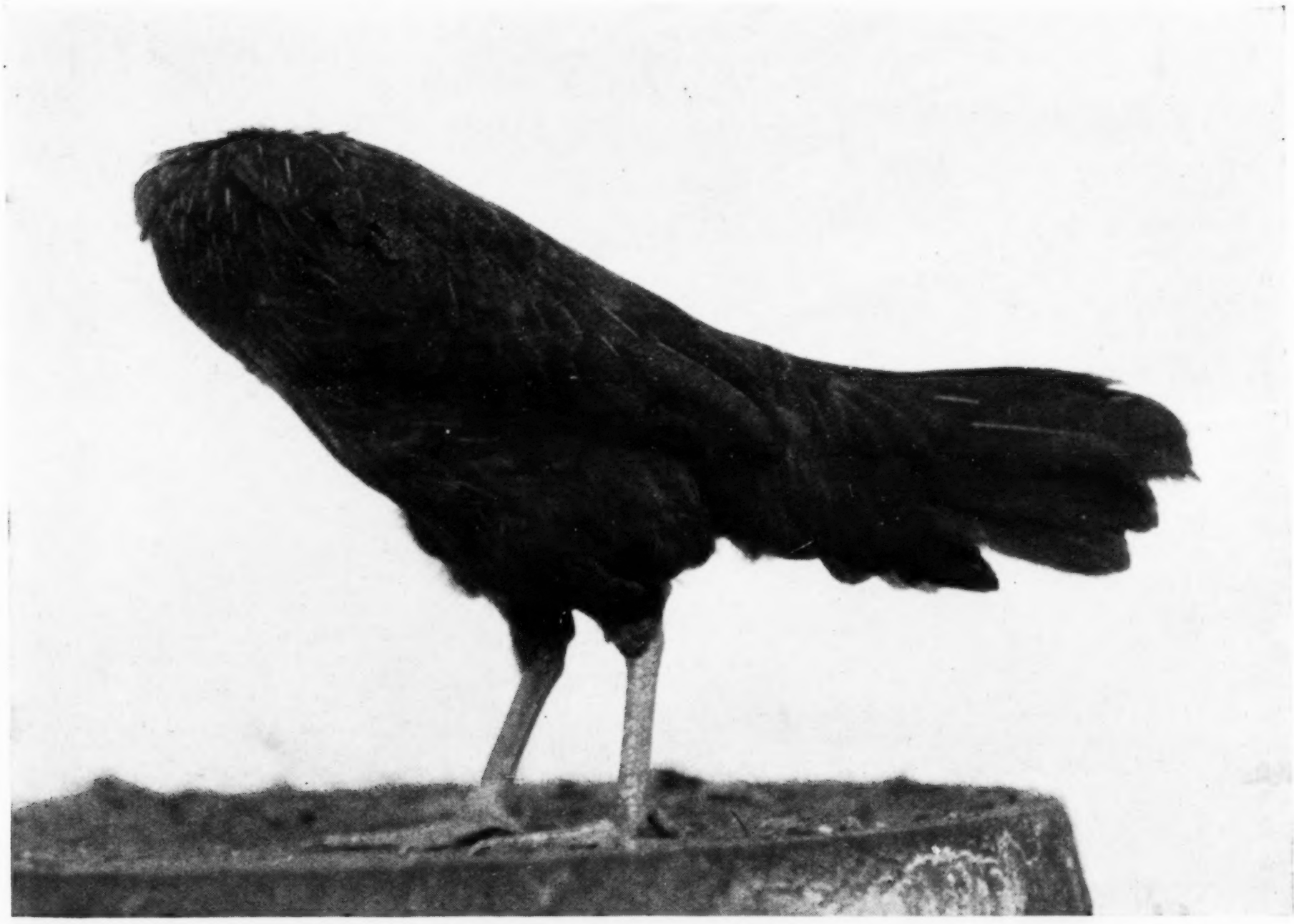

A HEADLESS HEN? — ONLY A GENE FOR CROOKED NECK!

A Short-Toed Family

Chromosomes of the Pineapple

A Dominant Mutation in Maize

Guiding Mental Growth

A Two-Headed Turtle

VOLUME 22 MAY, 1931 NUMBER 5

The American Genetic Association

An incorporated organization devoted to promoting a knowledge of the laws of heredity and their application to the improvement of plants, animals, and human racial stocks

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The

Journal of Heredity

Vol. XXII MAY, 1931 No. 5

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COMING

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Siamese Twins Unlike

The most closely associated of identical twins the most dissimilar, and a theory of twinning to account for this fact.

Nematode Resistance in Beans

Strains discovered that thrive in Nematode infested soil.

X-Ray Mutations in Cotton

Dwarfs, color chimeras, leaf shape reversions, and other changes brought about in plants from X-rayed seed.

The JOURNAL OF HEREDITY is published monthly by the AMERICAN GENETIC ASSOCIATION, at 1918-32 Harford Avenue, Baltimore, Md., and Victor Building, Washington, D. C. Address all communications regarding editorial matters and the business management of the Association to Room 306, Victor Building, Washington, D. C. Entered as second-class matter February 24, 1923, at the postoffice at Baltimore, Maryland. Acceptance for mailing at the special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized December 20, 1918. Contents copyrighted 1931 by the American Genetic Association. Unauthorized reproduction of material from THE JOURNAL not permitted. The title "Journal of Heredity" is registered as a trade-mark in the U. S. Patent Office.

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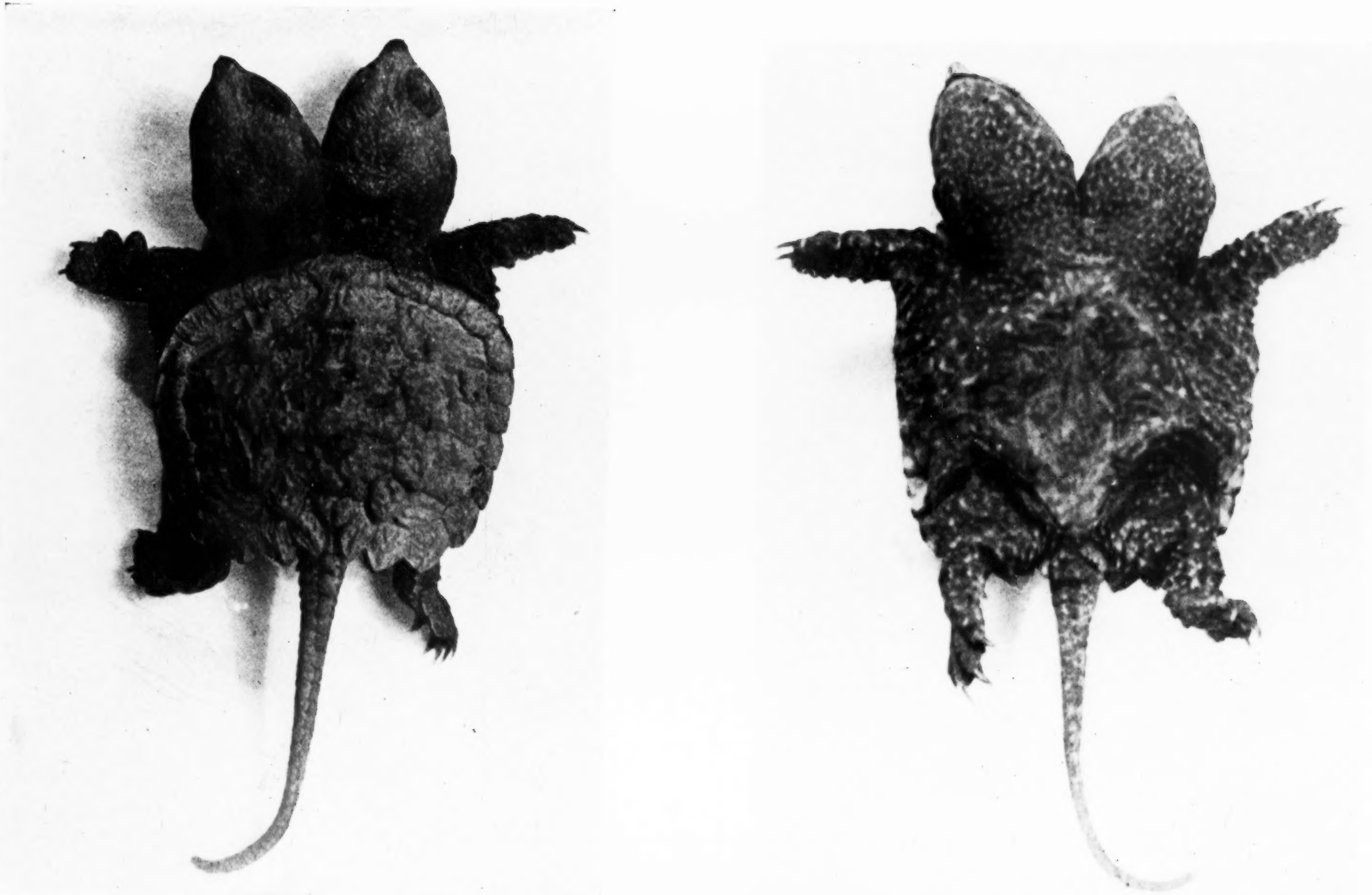

TWO HEADS, BUT OTHERWISE NORMAL

Frontispiece

Two-headed monsters rarely survive to maturity, but according to last reports this snapping turtle is still doing well and is now nearly a year old. With a pair of normal heads he ought to be able to comprehend both sides of any question, but it has been suggested that the two heads may spend their time trying to decide which one should be the boss

A TWO-HEADED TURTLE

J. A. CEDERSTROM

Department of Zoology, University of Minnesota

PLENTY OF HEADS

Figure 1

X-ray photograph of the two-headed turtle, showing branching of the vertebral column. Whether the turtle thinks with the heads simultaneously or alternately has not been determined. Each head seems to control its own side.

LIVING two-headed animals are comparatively rare. Possibly such monstrosities may occur often but are passed by unnoticed, though their striking appearance renders this unlikely. In humans, the Siamese Twins serve as a classic example of duality carried to its highest form. Occasionally dicephalous kittens and calves are reported, also all sorts of

monstrosities appear among fowls where chicks are hatched in wholesale numbers. As a rule, such monstrosities are either born dead or are short lived and often little is learned of their internal anatomy. Rarely are scientists able to secure these forms and rear them for any length of time. Early last October, the writer secured an unusual monstrosity in the form of a living dicephalous turtle of last summer's (1930) brood.

This turtle was found last September by two small boys at play on Enchanted Island, Lake Minnesota, near Minneapolis. The boys who found this turtle are Floyd Anderson and Willis Winther, both of this city. The boys disposed of it for a quarter to Mr. C. W. Cheney, an employee of the Northwesteern Fuel Company of this city, who gave it to the Department of Zoology, University of Minnesota.

This specimen was a common hard shell snapping turtle, *Chelydra serpentina*. The body, which was covered with a characteristic shell, was normal except for a slight hump, possessed four well developed legs, one tail, and a single cloacal opening. Anteriorly extended two active and completely formed necks and heads.

Difficulty was encountered in getting this turtle to eat. Consequently, it was turned over to the care of Mrs. Grace Wiley, Curator of the Natural History Museum of the Public Library in this city, who was rearing a number of small turtles. In company with these, it soon started feeding.

The heads apparently act independently of each other, feeding alternately or coordinately. It is, apparently, thriving and gaining in weight. It acts normally. Indications are that it is possible to raise this monstrosity to maturity. Observations on the turtle are being made and records kept of its growth. Several feet of film have been secured showing feeding and other activities of the animal.

It appears as though motor activities of each side of its body are directed by the brain on that side of the body.

X-ray photographs of the animal made last November (1930) showed that each neck has the usual number of vertebrae (eight). Apparently the last neck vertebra of each neck articulates with a separate free thoracic vertebra. X-ray photographs made on February 17, 1931, show these two free thoracic vertebrae to be fused. Posterior to these free thoracic vertebrae the vertebral column is single and apparently normal.

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GENETIC STUDIES OF THE PINEAPPLE

I. A Preliminary Report Upon the Chromosome Number and Meiosis in Seven Pineapple Varieties (*Annas Sativus* Lindl.) and in *Bromelia Pinguin* L.*

J. L. Collins and Kenneth R. Kerns

Experiment Station, Association Hawaiian Pineapple Canners, Honolulu, Hawaii

RECENT developments of the chromosome theory of heredity have demonstrated the valuable aid that a cytological study can render in laying plans for genetic studies and in interpreting genetic problems. A comprehensive genetic study of any species requires an examination of the chromosomal machinery of regular sexual reproduction and the chromosomal conditions in any atypical individuals of a population.

This paper on the chromosomes of the pineapple constitutes the first of a series of genetic studies upon *Ananas sativus* Lindl., and related species.

The following eight varieties grown at the Experiment Station of the Association of Hawaiian Pineapple Canners were used to supply pollen mother cells (P. M. C.) and root tip cells for the chromosome studies: (1) Cayenne, the variety grown commercially in Hawaii, (2) Queen, (3) Spiny Samoa, (4) Ruby, (5) Pernambuco, (6) Spiny Guatamala, (7) an F_1 hybrid produced by crossing Cayenne, with an unnamed wild type from Brazil and (8) *Bromelia pinguin* L.

Flower buds containing young anthers were fixed in Carnoy's solution and imbedded in paraffine. The sections were cut at 12 microns and stained with Haidenhain's iron alum haematoxlin.

Attempts to use Belling's iron-aceto-carmine method were not successful and some difficulty was encountered with the haematoxlin stain remaining in the cytoplasm but the latter was largely overcome by increasing the time in mordanting and in de-staining.

Root tips were secured from crowns and slips† grown in water cultures and in soil. They were fixed in Nawaschin's (1923) chromic acetic mixture, the sections cut 10 microns and stained in Haidenhain's iron alum haematoxlin.

The drawings were made with the aid of a camera lucida at a magnification of approximately 3500× for Figure 2 *A-H*; 1600× for Figure 2 *I-P*. The photomicrographs were taken with a Leitz microscope camera on a Leitz microscope using a 4 mm. apochromatic oil imm. objective and a 10× periplan ocular, giving a magnification of approximately 960×.

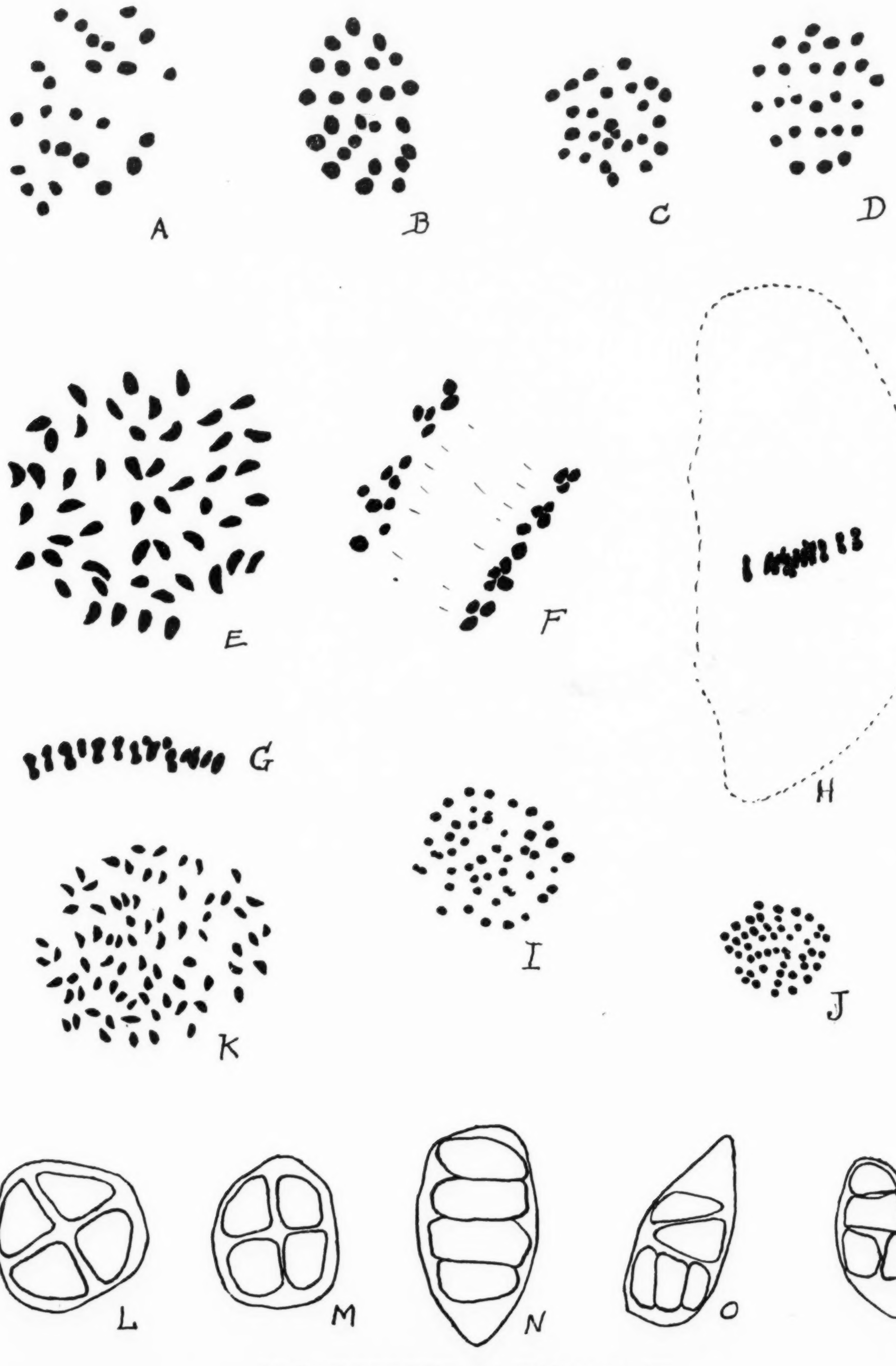
Chromosome Number and Meiotic Characteristics

The study of P. M. C. revealed 25 chromosomes in all the varieties at both heterotypic and homotypic divisions (Figure 2 *A, B, C, D*). Root tip cells of Cayenne, Ruby and Pernambuco contained 50 chromosomes as the diploid number (Figure 2 *E*).

Meiosis was primarily regular (Figure 2 *F, G, H*) and only rarely were there any indications of lagging chromosomes or other irregularities during either of the meiotic divisions. Some abnormal tetrads were observed (Figure 2 *N, O. P.*) and differences in size of the mature pollen grains were

*Technical Paper No. 13 of the Experiment Station of the Association of Hawaiian Pineapple Canners, University of Hawaii.

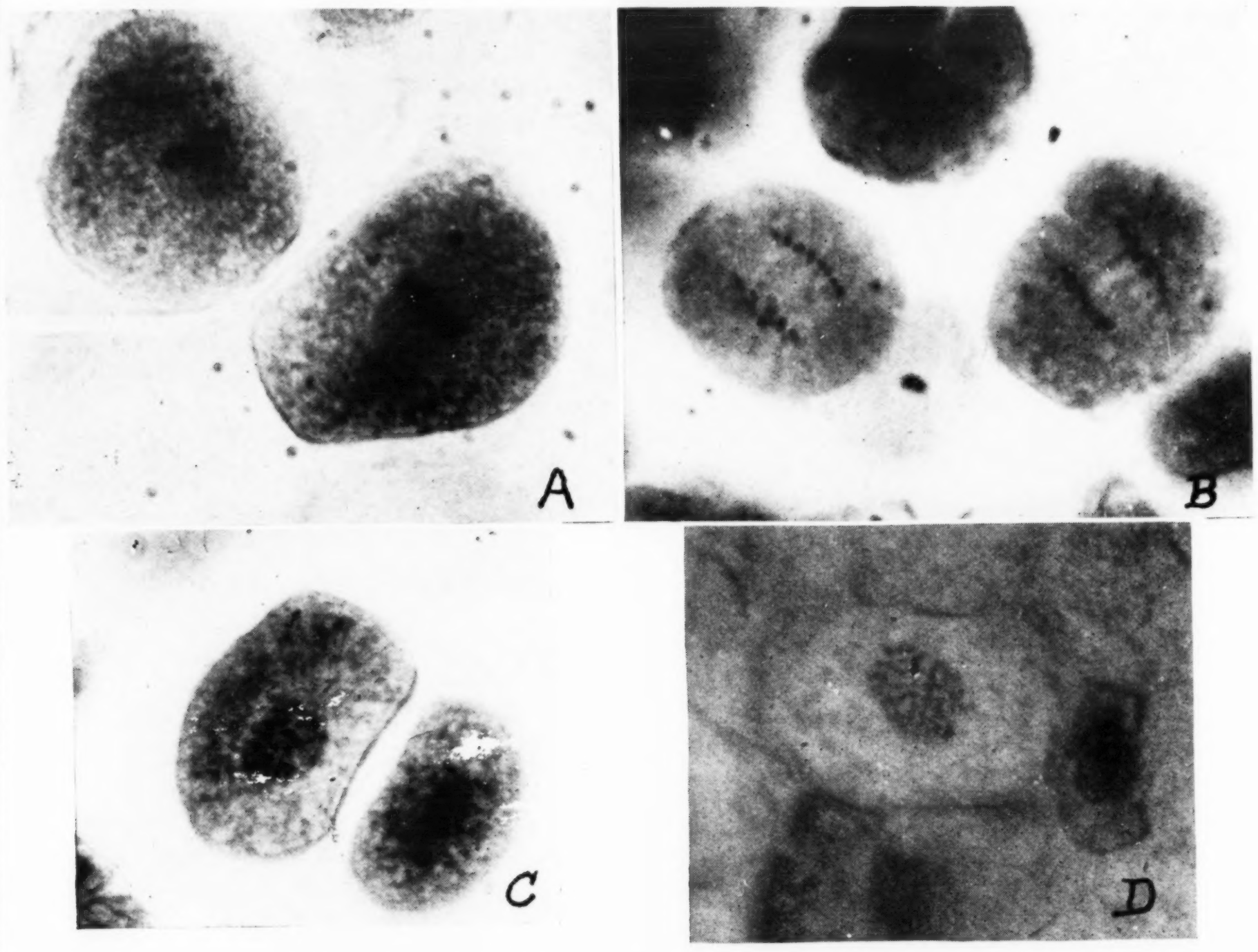
†The leaves at the top of the fruit constitute the crown while slips are buds or shoots which develop on the stem at the base of the fruit. These parts are used as cuttings to start new plants and supply many large root tips.



CHROMOSOMES OF PINEAPPLES

Figure 2

A-B, Haploid groups showing 25 chromosomes following reduction division in Pollen Mother Cells (P. M. C.) Cayenne. 3500×. *C*, *D*, Same from Pernambuco. *E*, 50 chromosomes in the nucleus of a root tip cell of Ruby. Note the slightly elongated shape as compared with the meiotic chromosomes above. *F*, Side view of anaphase of first meiotic division showing absence of lagging chromosomes. *G*, *H*, Side views of metaphase plates showing regularity of chromosome conjugation. *I*, *J*, Polar views showing 48 chromosomes at the reduction division in P. M. C. of *Bromelia pinguin* L. 1600×. *K*, The nucleus of a root tip cell of a triploid pineapple showing 74 chromosomes. *L*, *M*, Normal tetrads and *N*, *O*, and *P*, abnormal development of tetrads in Cayenne.



PHOTOMICROGRAPHS OF CHROMOSOMES

Figure 3

A, Side view of P. M. C. showing chromosomes at the metaphase I. *B*, Same as Figure *A*, but showing anaphase stage. These views are typical of many examined and illustrate the regularity of chromosome distribution. *C*, Polar view of chromosomes during the first meiotic division. The small spherical shape of the chromosomes is evident at this stage. *D*, Chromosomes in the nucleus of a root tip cell from Ruby.

common. This cytological evidence of meiotic regularity of the chromosomes of these pineapple varieties is supported by the regular Mendelian distribution of several plant characters which will be reported in detail in a subsequent paper.

In common with other members of the Bromeliaceae as reported by Taylor[4] and Billings,[1] the chromosomes of the pineapple were found to be very small and almost spherical in both P. M. C. and root tip cells (Figures 2 and 3).

The establishment of the diploid number as 50 and a regular type of meiosis in these several varieties is of more than ordinary interest in view of the fact that Heilborn[2] previously reported a somatic number of 75 and an irregular type of meiosis for material collected in Ecuador. His figures leave no doubt as to the correctness of this number for the material he examined and, as he points out, indicate a polyploid condition in this genus. The spherical shape of the chromosomes renders difficult the distinction between bivalent and univalent chromosomes. Heilborn, however, concluded that there were 30 bivalent and 15 univalent chromosomes at the heterotypic metaphase and that this race was, therefore, a hybrid between two other races with 30 and 45 as the haploid chromosome numbers. On the basis of

this conclusion he considered the fundamental haploid chromosome number for the genus to be 15 or 5.

Triploid Pineapples

It appears probable from our studies that Heilborn was dealing with a triploid race having three sets of 25 chromosomes. Such a triploid should exhibit 25_{11} and 25_1 chromosomes during meiosis. This explanation of the chromosome number found by Heilborn is supported by the fact that we have recently located six triploid plants in the F_1 hybrid population of approximately 8,000 plants produced by crossing Cayenne, $n = 25$ with a wild Brazil race, $n = 25$. These triploid plants have 75 chromosomes and the preliminary observations on the results of meiosis indicate irregularities in this process. Figure 2 *K* shows 74 chromosomes in a nucleus of a root tip cell of triploid plant.*

From the appearance of the triploids, they are judged to contain 50 Cayenne and 25 wild Brazil chromosomes (the latter race was the pollen parent in the cross). The number of chromosomes in these plants also furnishes confirmation of our opinion that the fundamental haploid number for the genus is more likely to be 25.

The chromosome number of a few other members of the Bromeliaceae has been determined. P. M. C. studies have shown 48 as the haploid number in *Bromelia pinquin* L. (Figure 2 *I, J*). These chromosomes appear to be much smaller than the less numerous ones of Ananas but this is due to the different magnifications used. Taylor[4] reports 25 as the haploid number for *Pitcairnia zanthocalyl* Mart., and 50 the diploid number for *Aechmea conspicuiarnata* Baker, while Billings[1] reported $n = 16$ for *Tillandsia usneoides*.

Summary

1. The haploid chromosome number was found to be 25 for seven varieties of *Ananas sativus*. A count of 50 was made in somatic cells from root tips of three of these varieties.

2. Meiosis appeared to be quite regular while mature pollen grains showed size differences.

3. *Bromelia pinguin*, a species closely related to the pineapple, was found to have $n = 48$ chromosomes and a regular type of meiosis.

4. Six triploid plants with 75 chromosomes are reported in a hybrid population produced by crossing two diploid varieties in which $n = 25$.

5. These investigations warrant the conclusion that Heilborn's pineapple plant with 75 somatic chromosomes was also a triploid.

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*A complete description of the morphological and cytological features of these triploids will appear later.

EUROPEAN BLACKBERRY SEEDLINGS AND HYBRIDS

In the Pacific Northwest

GEORGE M. DARROW*

TWO horticultural varieties of the European blackberry, the Evergreen and the Himalaya, have been planted extensively in the Pacific Northwest. The Evergreen was introduced there probably before 1860. In England it is known as the "Cut-leafed" or "American Cut-leaf" even though it was known in Europe as early as 1809. The Himalaya (Theodor Reimers of Germany) was introduced by Luther Burbank about 1889. In the Pacific Northwest both varieties are more productive than any varities of American origin, the Evergreen on the average yielding about 100 per cent and the Himalaya from 50 to 100 per cent more than the American varieties. The Evergreen produces a very firm fruit which is canned for use by the pie trade and to some extent as a dessert fruit. Its firmness is illustrated by the fact that commercially it is picked only at seven to ten day intervals in the Northwest. The Himalaya bears a soft, highly flavored fruit which cooks to pieces too much to make a highly desirable pie filling but which makes a highly flavored dessert fruit when canned. It is also liked by the preserving trade. Though both varieties are valuable sorts, a single variety possessing the more desirable points of each would be still more valuable. Such a variety should have the productiveness and firmness of the Evergreen and the high flavor of the Himalaya.

With this in mind some years ago crosses were made at the United States Plant Field Station at Glenn Dale, Maryland, using the Evergreen as the seed parent. Only two of the resulting seedlings proved to be true crosses, the others appeared to be identical with the Evergreen. In Maryland, fruit of both seedlings was too small to be of value. The others which were like the Evergreen were apparently false hybrids as obtained by Lidforss* when he crossed European blackberries. Besides crosses, hundreds of selfed seedlings of the Evergreen were grown at the United States Plant Field Station, all of which were identical with the Evergreen and were probably apomictical.

During 1930 the opportunity was offered to study the Evergreen and Himalaya and their seedlings further. Both sorts have seeded freely in the wild in western Oregon and Washington and it was expected that hybrids between the two would be found. A survey of forms in the wild was begun in August and continued through to November.

In the wild the Evergreen was more common than the Himalaya, in some localities such as a part of the Brewster Valley of Oregon, thousands of bushes of the Evergreen being seen but not a single wild Himalaya. In other localities counts in the wild indicate one bush of the Himalaya to three of the Evergreen. Both the Evergreen and Himalaya were common along roadsides, irrigation ditches or stream banks as far south as the base of the Siskiyou Mountains south of Ashland, Oregon,

*Lidforss, B. Resumé seiner Arbeiten über Rubus (Hinterlassenes Manuskript). *Zeitschr. ind. Abst. Vererbungsl.* 12: 1-13. 1914.

*Senior Pomologist, Bureau of Plant Industry, United States Department of Agriculture.

NORMAL AND VARIANT HIMALAYA LEAVES

Figure 4

To left, leaf of Himalaya blackberry; to right, leaf of the seedling variant called the "English" blackberry with shorter, less deeply toothed, densely hairy leaflets.

TOOTHED AND ENTIRE LEAVES

Figure 5

To left, laciniate leaf of typical Evergreen blackberry; to right, "broad leafed" variant of the Evergreen with the basal leaflets entire and the upper somewhat notched. Plants of the Evergreen variant with all leaflets entire and others with still more laciniate leaves are sometimes seen.

and nearly to the California line along the Oregon coast. In California only two wild Evergreen plants were seen, one near Mt. Shasta and the other along the coast highway about 150 miles south of the Oregon-California line. The Himalaya, however, was quite common along irrigation ditches and fence rows in parts of California but not in woodland or pastures as in western Oregon and Washington.

Evergreen in the Wild

In general, the Evergreen seedlings in the wild were all identical just as found by Lidforss with some European blackberries. The few variations found were chiefly in the division or laciniation of its leaflet and these variations reproduced exactly true from seed. Occasional plants were seen with leaves more finely divided than the common, while plants with less divisions or entire leaves were more frequent. In the Montesano Valley of Washington an entire-leafed form was very abundant, in some places being more common than the cut-leaf form. In that region even the cut-leafed forms were not as finely divided as the type. In the Brewster Valley of Oregon, however, all of the thousands of plants observed in the wild were of the typical cut-leaf form. In season of ripening and in size and flavor of fruit no differences were observed which could not be caused by differences in environment.

Evergreen Under Cultivation

The cultivated Evergreen plants have almost all been propagated from wild plants so that cultivated plantings are made up of propagations from hundreds of individual seedling plants. Most of these were probably taken without specific reference to their fruiting habits. Notwithstanding this they are remarkably uniform, and only an occasional bush can be found varying from the type. In a few instances, however, growers have propagated from selected wild bushes. The "Delsweet" is such a wide-leafed form propagated near Stayton, Oregon, which appears to be more productive and to have somewhat larger fruit of better quality (especially when canned) than the type. A thornless form, apparently a sport, has been found in the wild and is being propagated. The Western Washington Experiment Station at Puyallup has made a collection of variations and has several under trial.

Apparently most of the thousands of seedling Evergreen blackberries found in the wild are exactly like the parent and reproduce by apogamy. It seems probable that the bushes showing variations in leaf width are the result of sexual fertilization, but that under conditions in this region less than one in a hundred is a true seedling. Under such circumstances some improvement over the type may be possible by selection of wild plants, but breeding offers the greatest opportunity for improvement. Furthermore, the range of variation of the true seedlings of the Evergreen in the wild is relatively small as measured by variations resulting from breeding; and the variations are rare.

Himalaya in the Wild

The study of the wild forms of the Himalaya blackberry showed a greater range of variation than the Evergreen. The variations were more evident in the fruit than in other characteristics. Bushes bearing berries ripening earlier were found and others ripening much later. The berries varied in flavor, size and firmness, some being found with fruit nearly as firm as that of the Evergreen. Definite types tended to reappear in widely separated localities. One such type with canes, covered with red glandular hairs, with relatively short leaflets, and late-ripening firmer fruit was found at four places: near the coast south of Coos Bay, again 200 miles northeast in the Willamette Valley at Corvallis

and again in the Coast Range at Toledo, and in a garden at Chitwood. It was recognized as distinct and called the "English" blackberry at one point, but its distribution in the wild indicates that it is probably derived from the Himalaya. Whether the variant forms in the wild are crosses with the Evergreen, selfed seedlings or both is uncertain. Selfed seedlings raised at the United States Plant Field Station at Glenn Dale, Maryland were apparently all apomictical, exactly like the Himalaya. Though sterile or nearly sterile seedlings would be expected in tne case of both true crosses and of true seedlings, few or no sterile plants were found.

Himalaya Under Cultivation

Because the Himalaya was introduced later than the Evergreen and from the first was under cultivation, most of the cultivated fields have been propagated from the original stocks and are identical. However, one grower near Stayton, Oregon is growing a firmer form obtained from the wild and very many of the bushes in gardens are seedlings and variations.

Discussion

These two European varieties of blackberries have been distributed widely in the wild in western Oregon and Washington by birds and other agencies. Hitherto even the wild plants have been of economic value as the fruit has brought good prices. They are becoming a menace in some places where they have occupied pasture land and have crowded into roadways. In some localities weed killers have been used in late summer to eradicate them. Because of the extent of their distribution they are likely to be even more of a menace in the future. As better varieties of their type are cultivated, the value of the wild product will tend to lessen and the wild plants will represent a continually increasing danger. The "red-berry" mite was found widely distributed on the wild plants in 1930 and by destroying the value of the berries on affected plants has further lessened the value of the wild crop.

Some thirty collections of forms of hybrids or of seedlings of these two varieties which seemed to have economic possibilities were made in 1930 and established at the Oregon State College at Corvallis, Oregon. These will be brought into fruiting and compared. Some of these forms seem desirable enough to propagate for introduction. Still other desirable wild forms are likely to be found.

Lidforss noted that where he obtained true hybrids, the second generation seedlings were extremely variable. From this and from a study of the wild plants it seems likely that most of the wild variants are selfed seedlings of Himalaya while some are probably true crosses between Evergreen and Himalaya. In Lidforss' studies some kinds were found producing nearly all false hybrids, others produced about half true and half false hybrids, and still others still fewer false hybrids. The Evergreen apparently produces mostly false hybrids, that is, seedlings identical with the parent while Himalaya produces more true seedlings and more variants. At the United States Field Station selfed seedlings of one other European sort, Edward Langley, have been grown and so far as could be determined they were all identical with the parent.

In contrast to the European blackberries the American bush blackberries have not been reported as producing false hybrids, that is, their seedlings show the usual range of variation.

INHERITANCE IN POULTRY

Data on the Genetics of Vulture Hock, Hen Feathering and "Crooked Neck" in the Domestic Fowl

MORLEY A. JULL AND JOSEPH P. QUINN*

DURING recent years considerable progress has been made in determining the mode of the inheritance of a number of morphological and other characters in the domestic fowl. This brief paper supplies data on the inheritance of three morphological characters whose mode of inheritance has not as yet been definitely established.

Inheritance of Vulture Hock

Two standard American breeds of chicken, the Sultan and the Mille Fleur Booted Bantam, have vulture hocks as a characteristic of their morphological feathering development and in this respect differ from most other American breeds, although there are breeds in Europe with the same characteristic. At the U. S. Animal Husbandry Experiment Farm, Beltsville, Maryland, a male with a very prominently developed vulture hock was secured from an F_2 progeny of a cross between the Silkie and the White Leghorn. Known as male No. 90 he was mated to a pen of Rhode Island Red females, absence of vulture hocks being a characteristic of this breed. The male and one of the females are shown in Figure 6—P_1 generation.

This mating produced 202 F_1 males and females that reached maturity and none had vulture hocks. A representative male, No. 227, and a representative female, No. 5208, are shown in Figure 6 (F_1).

The F_1 male No. 227 was mated to a pen of F_1 females, including female No. 5208, and this mating produced 111 F_2 males and females. Among the F_2 progeny the distribution of vulture hock was as follows:

	No vulture hock	*Vulture hock*
63 F_2 males	45	18
48 F_2 females	37	11
111 F_2 progeny	82	29

The evidence shows that not only is vulture hock recessive to absence of vulture hock, as Davenport[1] suggested, but that a single gene is responsible for the development of the character. A 3:1 ratio would lead to the expectation of progeny in the proportion of 83.25:27.75, very close to the results secured.

Representatives of the F_2 progeny are shown in Figure 6.

It is interesting to note that the development of vulture hock appears to be accompanied by the development of leg-feathering, since none of the F_2 progeny (3 males and 5 females) having clean shanks had vulture hocks. Among the vulture hock progeny, 17 were classified as having medium-feathered shanks and 12 were classified as having heavily-feathered shanks. There were four other birds with heavily-feathered shanks that did not have vulture hocks. The apparent relationship between the development of vulture hocks and feathered shanks has been reported by Davenport[1] and Dunn and Jull[2] though the nature of the genetic relationship has not been analyzed.

Inheritance of Hen-Feathering

Among the various American standard breeds of chicken, the Campines and Sebright Bantams are known as "hen-feathered" breeds, inasmuch as in these breeds the male hackle and saddle feathers are of the same shape, color, and relatively the same length as

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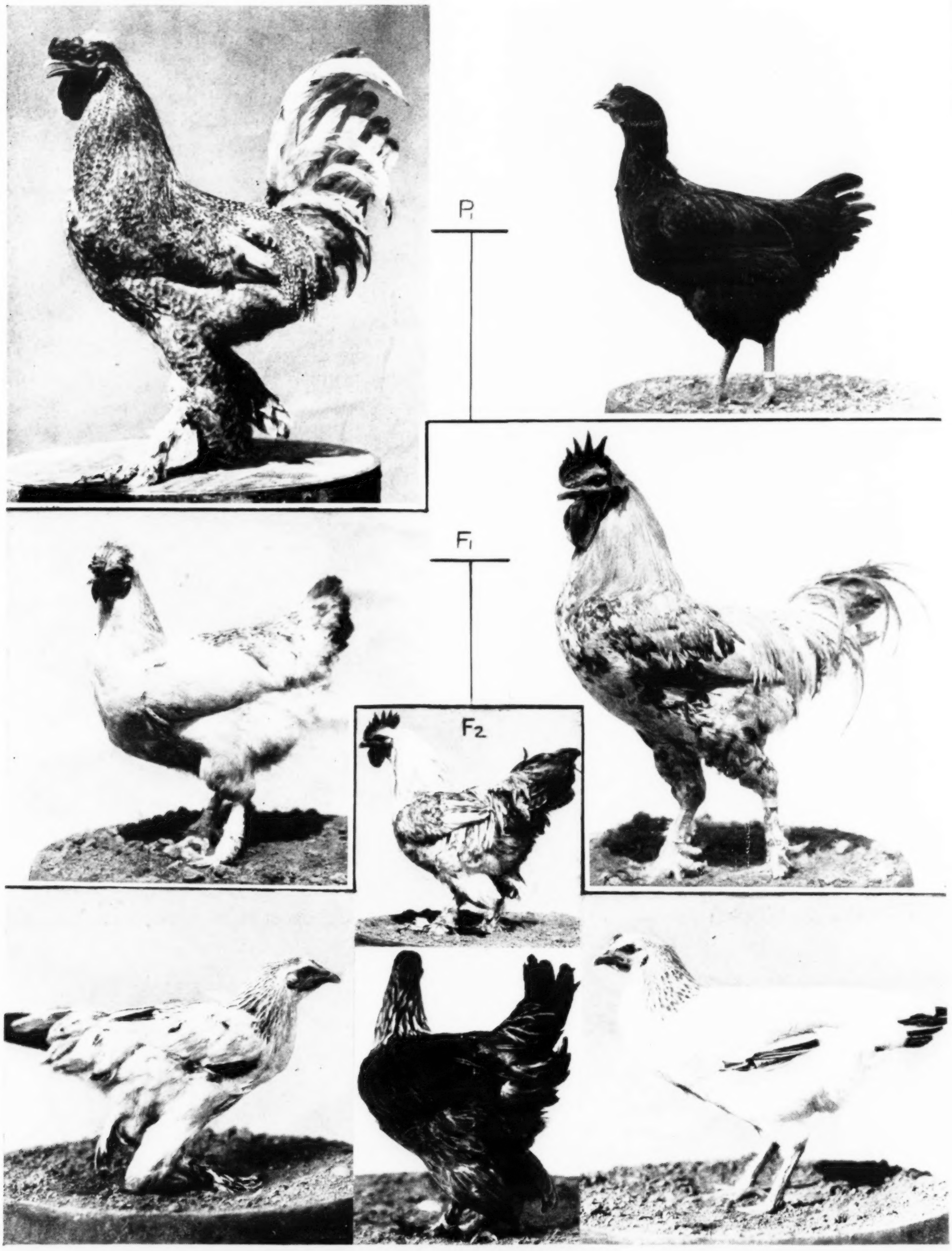
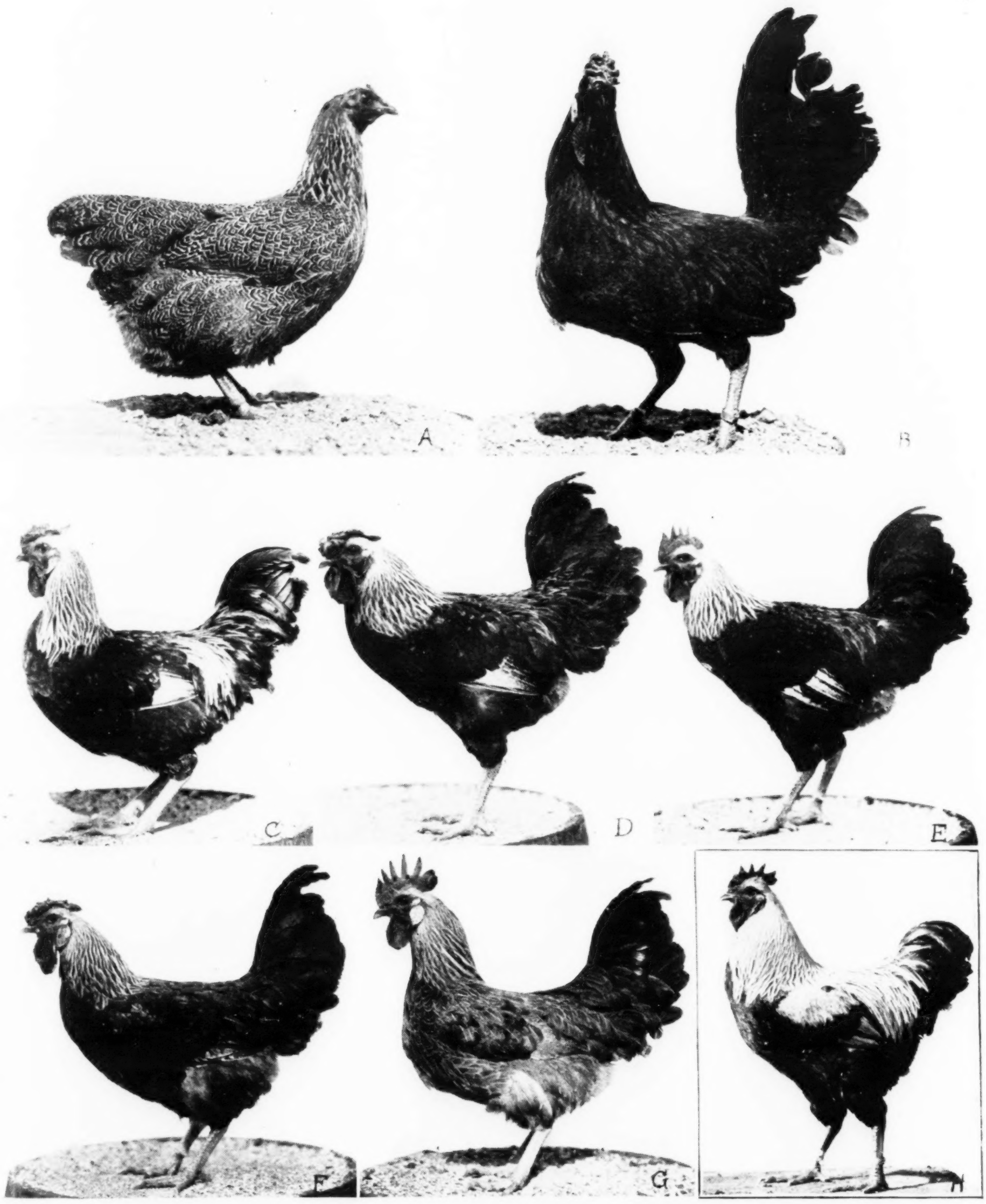


INHERITANCE OF VULTURE HOCK

Figure 6

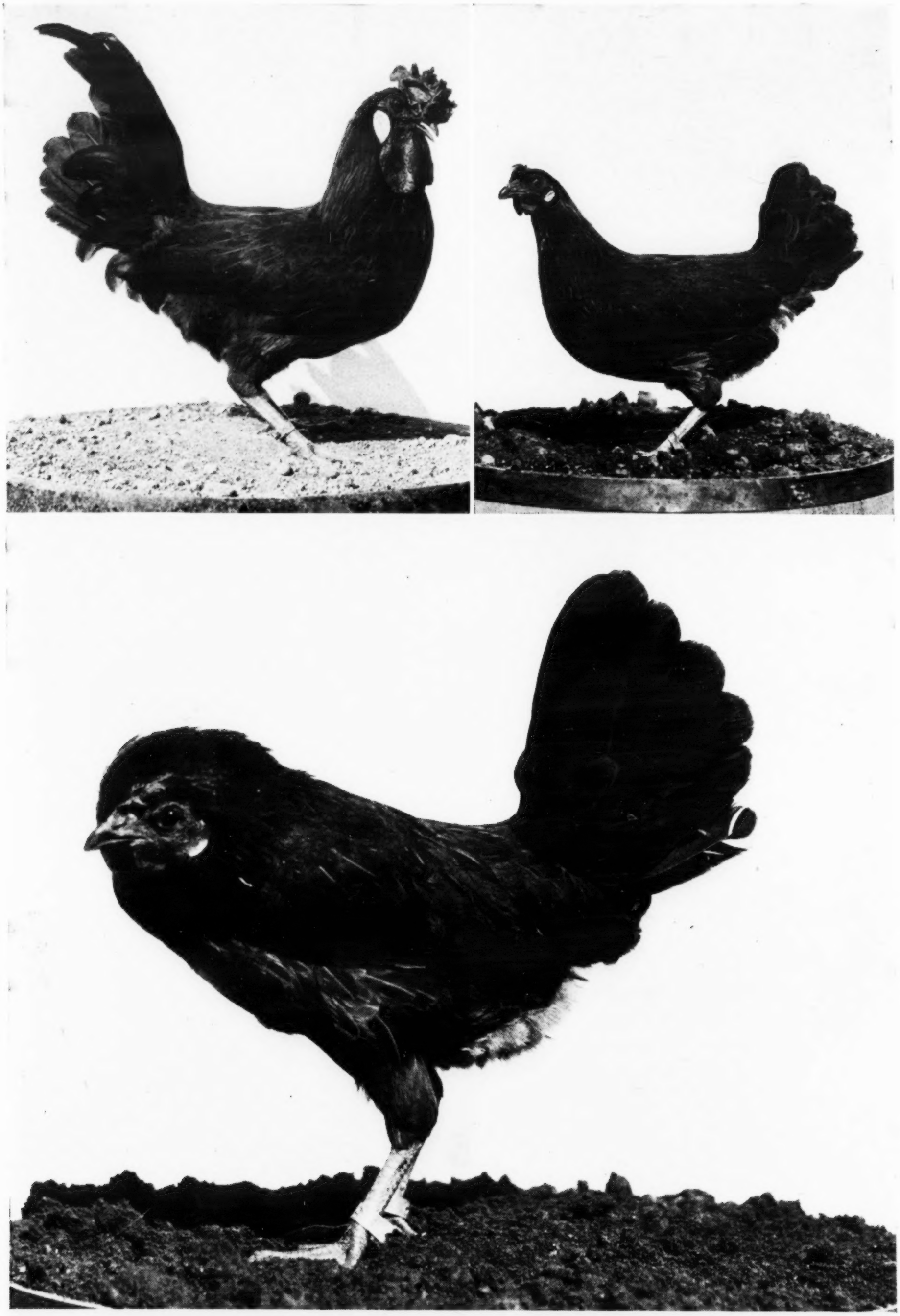
The cock shown in the P_1 generation was an F_2 of a Silkie-White leghorn cross. Mated with Rhode Island Red females he produced a progeny of 202, all of which lacked vulture hocks. In the next generation the distribution was 82 without and 29 with vulture hock, almost exactly a 3:1 ratio. Three vulture hock F_2's are shown here, and one clean-shanked pullet without vulture hock.



INHERITANCE OF HEN-FEATHERING

Figure 7

In a cross between a silver-penciled Plymouth Rock female (*A*) and a hen-feathered Brown Leghorn male (*B*), the male affspring (*C*-*G*) showed varying degrees of hen-feathering. A cock-feathered silver pencilled Plymouth Rock male is shown (*H*) for comparison.



INHERITANCE OF CROOKED NECK

Figure 8

Above: Hen-feathered Brown Leghorn male and female, both heterozygous for the defect *Below*: Crooked-necked segregate from this mating. About a quarter of the offspring of such heterozygous fowls are crooked-necked.

HEADLESS—OR SIDE-HEADED?

Figure 9

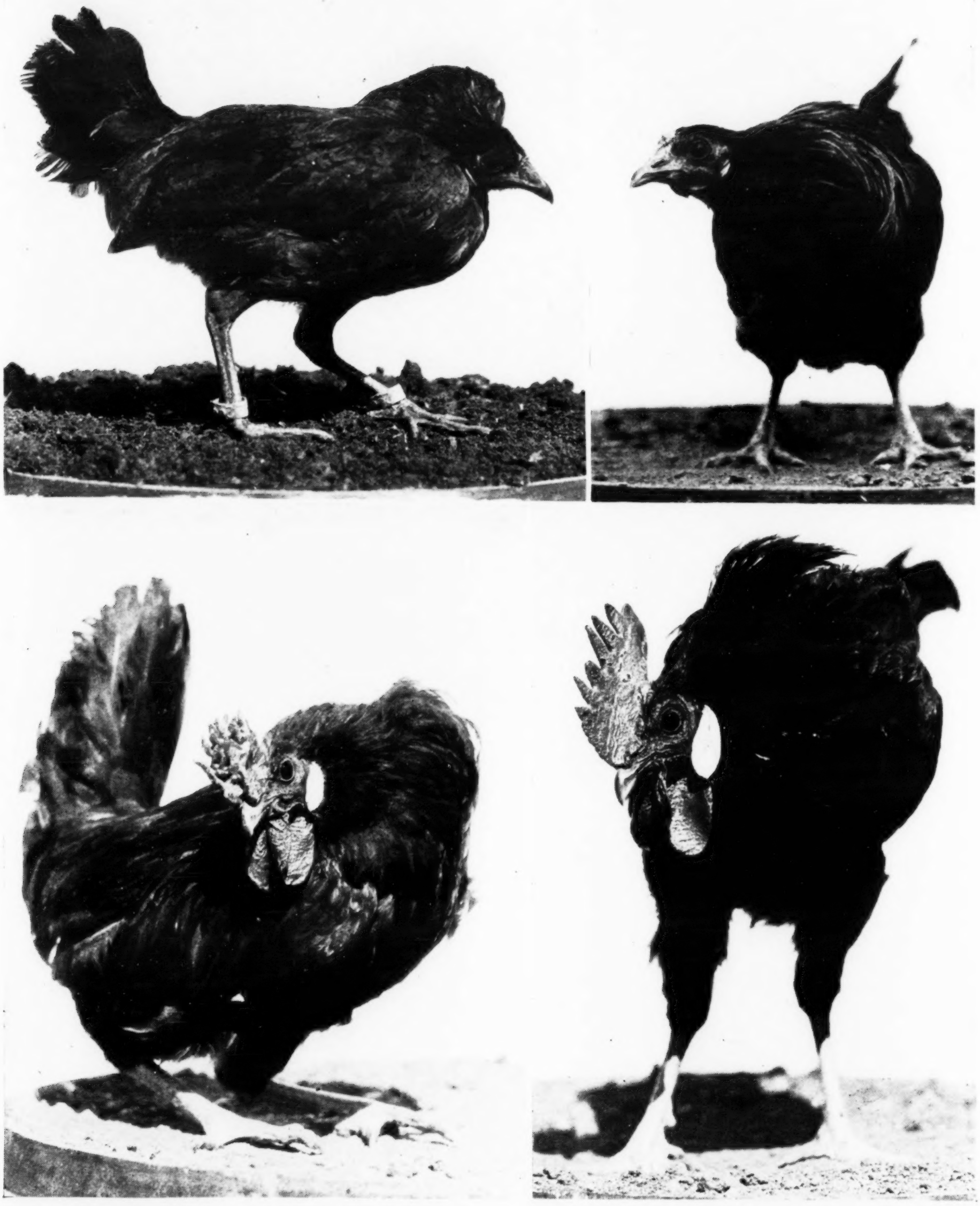
This hen has a head—only she carries it on the other side. In swine there are genes that cause headless monsters, but this gene in this case only *seems* to cause a headless fowl.

in the female. The observation of Morgan[4, 5] and Punnett and Bailey,[7] go to show that hen-feathering is dominant to cock-feathering and is apparently inherited on a monofactorial basis. Jull and Quinn[3] however, were led to believe that modifying factors are involved.

A hen-feathered Brown Leghorn male, shown in Figure *7B*, produced at the U. S. Animal Husbandry Experiment Farm, Beltsville, Maryland, was mated to a pen of Silver Penciled Plymouth Rock females, one of which is shown in Figure *7A*. The purebred Silver Penciled Plymouth Rock male differs materially from the female in the hackle and saddle, as shown in Figure *7H*.

The male progeny of the mating showed considerable variation in respect to the development of the hackle and saddle feathers. Of 75 males produced, all showed some modification in the length and pointed character of the hackle and saddle feathers. Representative specimens of five general groups are shown in Figure *7 C, D, E, F,* and *G*. There were 54 birds that resembled the one shown in Figure *7 C*, 9 resembling the one shown in Figure *7 D*, *7* resembling the one shown in Figure *7 E*, 3 resembling the one shown in Figure *7 F*, and *2* completely hen-feathered as illustrated in Figure *7 G*.

Punnett[6] has observed that cockerels intermediate for hen feathering become hen feathered after the first molt and he suggests that intermediate stages in the development of hen feathering may depend upon the immaturity or maturity of the testes. The testes of a number of the cocker-



OTHER "CROOKED NECKS"

Figure 10

Progeny of heterozygous fowls, showing expression of the crooked-neck condition. The crooked-neck fowls leave no progeny, so that the condition cannot be perpetuated.

els in this experiment were examined and there was no difference in size between any two groups classified according to hen-feathering, although it is possible that the degree of hen-feathering represents an expression of the functioning ability of the testis, independent of size, for the suppression of cock-feathering.

At the same time, since the inheritance of hen feathering has been observed to be due to a single gene, it seems probable in the light of the results reported in this paper that modifying factors are involved.

Punnett suggests the possibility of the existence of genetic differences between cockerels which are of the intermediate type and those which are fully hen feathered from the start. Cockerels representing the different classes of hen-feathered condition shown in Figure 7 provide the means of testing this theory, the proof of which has not yet been determined.

Inheritance of "Crooked Neck"

In a study of the inheritance of hen-feathering in Brown Leghorns at the U. S. Animal Husbandry Experiment Farm, Beltsville, Maryland, there appeared seven birds in one of the matings in 1926 with decidedly "crooked necks." The simultaneous appearance of seven such abnormal birds in one mating led to an analysis of the results and it was found that they were produced by three different dams in a total population of 39. It became apparent at once that not only was the crooked-neck condition inherited but also that it was probably inherited on a mono-factorial basis.

The defective condition did not appear in the chicks at the time of hatching nor until they were about half grown. In the majority of cases the neck was twisted to the right.

An examination of a number of the necks of affected birds revealed but little definite information as to the cause of the defect. As nearly as could be determined, however, the condition was probably caused by a cessation in the growth of or the misplacement of one or more of the numerous ligaments of the vertebrae.

Figure 8 shows normal birds heterozygous for the defect and one of their offspring having a crooked neck. Other affected birds from such matings are shown in Figures 9 and 10.

The "crooked neck" defect appeared in both males and females but attempts to interbreed birds with the defect and mate them with normal birds failed because the males were unable to mate with females and the "crooked-neck" females rarely laid any eggs. This was apparently due to the fact that as the birds grew older the defective condition became worse so that the birds eventually could not even eat, much less walk normally.

Subsequent to the appearance of the seven defective birds in 1926, males and females heterozygous for the recessive defect were mated and the condition of the neck observed in the progeny. The results are given in Table I.

There were 129 normal progeny and 27 "crooked-neck" progeny and if a single gene is involved the expected proportion is 117 to 39. The results secured are reasonably close to expectation and the conclusion seems justified that the defect is inherited on a mono-factorial basis.

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TABLE I.—The number of normal and "crooked-neck" progeny secured from matings of sires and dams heterozygous for the defect.

Year	*Mating Sire*	*No. Dam*	*Dam No.*	*Normal progeny*	*"Crooked-neck" progeny*
1926	1	232	228	7	2
1926	1	232	219	14	2
1926	1	232	223	11	3
1927	152	815	805	6	1
1927	152	815	806	12	1
1928	250	70	4164	4	1
1928	250	70	4165	18	1
1928	250	70	4222	7	3
1928	250	70	4224	7	4
1928	252	67	4427	13	1
1928	252	67	4490	15	3
1928	252	67	4495	1	1
1928	252	67	4498	5	2
1928	252	67	4501	9	2
Totals				129	27
Expected on a 3:1 ratio				117	39

The Power Plant of Life

THE EXCHANGE OF ENERGY BETWEEN MAN AND THE ENVIRONMENT. By L. H. NEWBURGH, M. D., and MARGARET WOODWELL JOHNSTON, PH. D. Pp. 1-96. $2.00. Charles C. Thomas, Springfield, Ohio. 1930.

THE materials comprising this volume were originally presented to a group of junior medical students with the idea of enlarging their conception of the life processes. Part I dealing with calorimetry discusses the historical development of the science of nutrition, and present day methods of measuring energy transformations, as an outgrowth of the fact that the law of the conservation of energy applies with equal force to living creatures as well as to the inanimate world. Part II is concerned with the nature of the insensible loss of weight, the environment, and insensible loss applications, and the systematic determination of the character of the energy exchange.

Now measurable phenomena permit the mind to obtain the most concrete idea of a mechanism, and it is shown that simple methods makes possible: (1) the determination of the total transformation of energy by man; (2) the kinds and amounts of materials oxidized by him in order to convert potential energy into kinetic energy; (3) the relation between the inflow of potential energy as found and the total transformation of energy; (4) the amount of tissue contributed by the organism when the inflow of energy is less than the outflow. Such a quantitative analysis of the manner in which man deals with the potential energy at his disposal furnishes an excellent opportunity to understand the fundamental relationship upon which the living organism is entirely dependent. This relationship the book summarizes in an excellent and objective manner.

N. M. GRIER.

HERITABLE CHARACTERS IN MAIZE

XL—Ragged, a Dominant Character, Linked with A_1 Ts_4 and D_1*

R. A. Brink, *University of Wisconsin, Madison*
and
P. H. Senn, *University of Florida, Gainesville*

THE grand scale upon which corn improvement is being carried forward in America brings hundreds of thousands of plants under the scrutiny of breeders each year. The repeated self-pollination, which is an integral part of the breeding procedure, serves to reveal in a most striking way the heterogeneous make-up of maize varieties. Characters which are rarely or never observed in open pollinated stocks come to light in large numbers in the inbred lines. The greater proportion of these are recessives which doubtless have existed in the open pollinated stock for many generations shielded by their respective dominant allelomorphs. It is known that from time to time, however, new characters arise by mutation. These likewise are nearly always recessive in behavior. The occurrence of a dominant mutation is, in fact, a rare event.

To the corn breeder the abnormalities cropping out in large numbers in inbred lines and the occasional ones arising by mutation are things to be gotten rid of. They more or less profoundly interfere with the development of the plant and limit its productivity. The student of heredity on the other hand, finds in these clear-cut characters just the materials he needs in analysing the genetic composition of the corn plant. Having once determined the position in the chromosomes of the gene governing a character, the latter may be used henceforth to mark the region involved. The maps which are thus constructed form an important part of the geneticist's analytical equipment. Their usefulness is closely related to their degree of completeness. In corn there are still long regions in the chromosomes without genetic labels. Further linkage studies are required to narrow these gaps and provide the basis for a closer analysis of the various hereditary phenomena encountered in the plant.

Dominant mutations are particularly helpful for genetic work. In linkage tests the unknown, which is usually a recessive, may be outcrossed to a stock carrying a dominant marker and a coupling series obtained in F_1. Backcrossing the hybrid to the unknown consequently gives a zygotic distribution which reflects directly the proportions in which the four possible types of gametes are formed by the double heterozygote. When a recessive character is employed as the marker it is necessary, of course, to produce an F_2 in order to obtain the double recessive for the crucial genetic test. If linkage obtains, and is close, a large F_2 population may have to be reared to secure the required tester stock.

The Ragged Character

The character ragged, a preliminary account of whose linkage relations is given in this paper, was first observed in a single plant growing in a block of sweet corn hybrids at the Agricultural Experiment Station, Madison, Wisconsin, in 1927. The original ragged in-

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*Papers from the Department of Genetics, Agricultural Experiment Station, University of Wisconsin, No. 115. Published with the approval of the Director of the Station.

RAGGED AND NORMAL LEAVES

Figure 11

Leaves from ragged maize plants (right and left) and from a normal plant (center) at the same node. The ragged leaves are smaller and show conspicuous chlorotic areas which are frequently perforated.

dividual occurred at the end of a row and several inches out of line with the other plants. It is not certain, therefore, that it actually belonged to the progeny which it adjoined. A crop of field corn had been raised on the area the previous year but it is evident that the ragged individual was not a volunteer since it was found to be carrying the gene for sugary endosperm. The displacement from the row was probably accidental and the divergent character of the plant the result of mutation.

Pollen from the ragged plant when used in crosses gave rise to both ragged and normal individuals in approximately equal numbers. The new character, therefore, is governed by a single dominant gene and the original plant was heterozygous.

The symbol *Rg* has been chosen to represent the dominant ragged gene; its normal allelomorph is *rg*.

The name, ragged, was applied to the mutant as descriptive of the torn appearance of its foliage at maturity. The seedlings are indistinguishable from normal. Shortly before the flowering stage, however, longitudinal chlorotic areas appear in the leaves. These areas increase in length as the plant grows. The vascular bundles may break in one or more places and the leaves fail to attain the normal size. Frequently all the foliage on the plant shows the lesions although in some lines only the upper leaves are conspicuously affected. Classification is best made at the flowering period or later. Soon after the appearance of lesions the leaf tissue begins to break apart as shown in Figure 11. A typical ragged plant at this stage is represented in Figure 12. If whipped in the wind the leaves rapidly tear apart giving the plant a very tattered appearance. At maturity little more of the shoot may remain than the culm, ear and tassel.

Inheritance of Ragged

The ragged character does not appear to reduce pollen production markedly. Some plants fail to form ears but in the heterozygote, at least, seed production, generally speaking, is sufficient for genetic purposes. In segregating progenies the proportion of ragged plants conforms rather closely to Mendelian expectation. In 13 families, for example, resulting from backcrossing heterozygous ragged plants to the normal type, 919 ragged and 914 normal plants were obtained. Within each of the progenies the fit to a 1:1 ratio was reasonably close. The normal plants from progenies segregating ragged give only normal offspring.

One progeny raised from an *Rg rg* plant selfed contained 86 ragged and 46 normal plants. This is a deviation of 13 ± 3.36 plants from the distribution expected on the 3:1 basis and would be expected but rarely as a matter of chance. The observed values, on the other hand, fit a 2:1 ratio very closely. It might appear from this result that the *Rg Rg* combination is lethal. A family of 184 plants obtained from an *Rg rg* × *Rg rg* mating, however, contained 132 *Rg* and 52 *rg* individuals. This is a deviation from the numbers expected on the 3:1 basis of only 6 ± 4.0 plants. Further evidence is needed regarding the possible nonappearance of the homozygous ragged genotype.

Results are available from linkage tests of the *Rg rg* pair with a series of genes whose positions in the chromosomes have been determined rather definitely. In these experiments the ragged type was outcrossed to the tester stock and the hybrid backcrossed to the tester, which in these cases is double recessive. In Table I the distributions are given for ragged and a number of characters which are apparently inherited independently of it. In the case of *c* and *j* the deviations from expectation on the basis of random assortment are rather large but there is no clear evidence of linkage.

Linkage Relations

The first linkage discovered with ragged was with a dwarf which appeared some years ago at Madison in

a Chinese flint variety. The dwarf had been provisionally designated d_5 pending the outcome of tests for possible identity with some one of the dwarfs already known. During the past summer (1930) Dr. Burnham at Cornell University informed us that H. S. Perry at that institution had obtained evidence showing that d_1 (Emerson, 1912) and d_5 were the same. The senior writer has recently grown in the greenhouse three progenies from crosses of the type $D_1\, d_1 \times d_5$ obtaining talls and dwarfs in the following proportions: 40:33, 43:40 and 47:54. These results confirm Perry's conclusions that d_1 and d_5 are the same or at least allelomorphic.

In Table II the distribution in a backcross population of Rg and d_1 is shown. There are 13 recombinations in a population of 109, which gives 11.9 per cent crossing over.

Ragged likewise is linked with tassel seed-4 (ts_4) as the results in Table III show. There are five recombinations in the backcross population of 288 individuals, giving a percentage crossing over of 1.7.

Phipps[3] has found 44.8 per cent recombination between a_1, a gene for anthocyanin, and ts_4 and concludes that, while the evidence is not conclusive, linkage is indicated. That a_1 may belong to the same linkage group as ts_4 and Rg is further borne out by the relationship which has been found between Rg and a_1. Two families from the backcross $Rg\ A_1\ rg\ a_1 \times rg\ a_I$, containing 288 and 232 plants, respectively, were classified. As shown in Table IV, the one progeny gave 38.5 per cent recombination and the other progeny 46.1 per cent. The net amount of recombination is 41.9 per cent. Since Rg and ts_4 give less than two per cent crossing over, this value is about what would be expected for Rg and a_1, if as the earlier results tend to show, the latter gene is actually linked with ts_4.

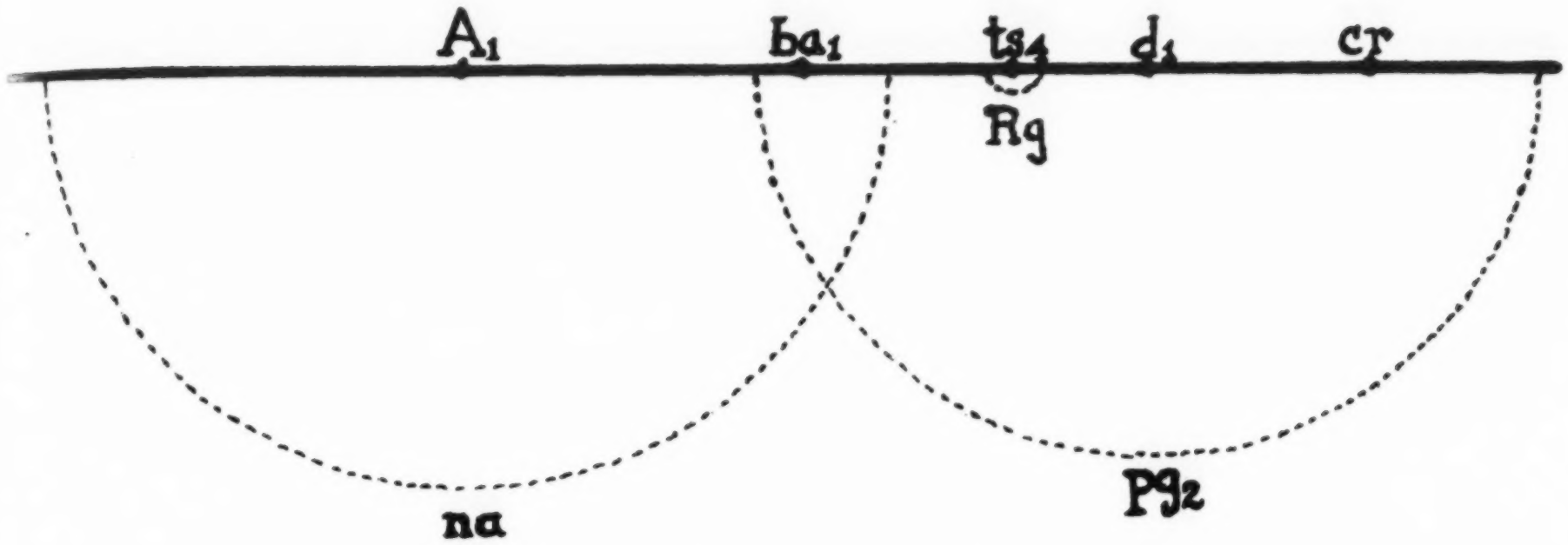
It has been tentatively considered that ts_4 and d_1 belonged to different linkage groups.* Demerec[1] has shown

A RAGGED PLANT

Figure 12

A typical ragged maize plant at the flowering stage. The stake at the base of the plant is two feet in length.

that a gene for pale green (pg_2) is linked with d_1 giving about 32 per cent crossing over with it. As has been shown in this paper, ragged is clearly



LINKAGE RELATIONS OF Rg GENE

Figure 13

The genes definitely located are shown in their relative crossover positions on the map. The location of those still in doubt is shown by the dotted circles.

linked with ts_4 and d_1 and possibly loosely linked with the a_1 factor. It would appear probable, therefore, that the two groups a_1-ts_4 and d_1-pg_2, which have been tentatively recognized as distinct heretofore, are in reality but one.

Additional Evidence From Cornell University

Evidence corroborating the conclusion arrived at above on the basis of the linkage relations of the ragged character, that the two groups formerly designated a_1-ts_4 and d_1-pg_2 are one, is afforded by some results obtained during the past season at Cornell University. At the suggestion of Dr. R. A. Emerson and with the approval of the workers concerned, brief mention of these findings will be made.

During the past season J. D. J. Hofmeyr obtained F_2 data showing that barren stalk-1 (ba_1) gives approximately 31 per cent recombination with a_1, about 11 per cent with nana (na) and about 33 per cent with d_1. Hofmeyr infers that the order is a_1—ba_1—na—d_1. Li (unpublished) had earlier shown that na is linked with a_1, the two genes being about 35 units apart. There is some doubt regarding the position of na with reference to a_1 and ts_4. In two progenies grown by the senior author of the present paper in 1930 from selfed $Na\ na\ Ts_4\ ts_4$ plants the two pairs of characters appeared to assort independently, indicating that na lies on the side of a_1 remote from ts_4. This is not in accordance with Hofmeyr's results. The validity of our evidence, however, is open to question since the plants made such an unsatisfactory growth that less than half of them (including the dwarfs) could be classified for ts_4.

A few years ago Emerson (unpublished) found that crinkly (cr) gives about 18 per cent recombination with d_1. Dr. Emerson has kindly sent us the count on a 1930 F_2 culture from an $A\ a\ Ts_4\ ts_4\ D_1\ d_1\ Cr\ cr$ plant selfed, which shows clearly that ts_4 is linked with d_1 and with cr and that the order of the genes is very probably a_1—ts_4—d_1—cr.

Dr. B. McClintock of Cornell University obtained a count in 1930 on a small progeny segregating a_1 and cr from a selfed plant trisomic for the a_1 chromosome. The numbers are few but the distribution of both pairs of characters is in accordance with expectation on the trisomic basis.

The evidence obtained on the linkage relations of the ragged character

*Summary of linkage in Maize (Mimeographed). Dept. of Plant Breeding, Cornell Univ., Ithaca, N. Y. 1929.

at the University of Wisconsin during the past season and the above mentioned facts simultaneously gathered at Cornell University, together with the relevant data earlier obtained at the latter institution, are summarized in the accompanying outline chromosome map. Where the sequence of the genes is still uncertain semicircles in broken line are used.

Acknowledgements

We are indebted to Dr. C. R. Burnham, formerly assistant in Genetics at the University of Wisconsin, for making a number of the crosses referred to in this paper and for permission to use the data regarding the behavior of bm_2 and *Rg*. Mr. H. S. Perry of Cornell University has kindly permitted us to cite his unpublished observations regarding the identity of the dwarf, tentatively named d_5, with d_1. The willingness of Professor Emerson and his associates that a summary of their linkage findings be included in the present paper has made it possible to map five genes in the group with considerable confidence as to the order.

Summary

1. A character in maize termed "ragged," is described. The form derives its name from the tattered appearance of the foliage at maturity.

2. Ragged plants differ from normal corn in a single dominant gene *Rg*.

3. The character is one which is well suited for genetic purposes. In segregating progenies ragged plants appear to be as vigorous as their normal sibs during early growth. The plants form pollen abundantly and *Rg rg* plants, at least, frequently bear a fair amount of seed. At the flowering period *Rg* plants are sharply differentiated from the normal type.

4. *Rg* appears to be inherited independently of *c, sh, wx, gl*$_1$, *f, j, bt* and bm_2.

5. In backcross progenies 1.7 per cent crossing over was found between *Rg* and ts_4. *Rg* and d_1 show 11.9 per cent crossing over. In two backcross families comprising 520 plants 41.9 per cent recombination was observed between *Rg* and the anthocyanin gene a_1.

TABLE I—Backcross results from coupling series involving the *Rg, rg* pair and the genes shown in column 2.

Group	Gene	Rg X	Rg x	rg X	rg x	Percentage recombination
I	c	26	37	18	43	44.3
I	wx	20	43	22	39	52.4
VI	f	not classified		67	60	52.8
VII	gl_1	43	54	33	35	52.7
VIII	bt	73	34	69	35	48.8
Unplaced	j	not classified		50	65	43.5
Unplaced	bm_2	not classified		78	73	51.6

Legend—Table I.—*c*=white aleurone; *wx*=wa xy; *f*=fine striped; *gl*$_1$=glossy; *bt*=brittle: *j*=japonica; bm_2=brown midrib. *X* and *x* are used in the table to represent the dominant and recessive members of the marker pairs, *Cc, Wx, wx*, etc.

TABLE II—Results of the backcross *Rg* D_1. *rg* d_1 × *rg* d_1.

Pedigree Number	Parental Combinations		Recombinations		Percentage crossing over
	Rg D_1	rg d_1	Rg d_1	rg D_1	
L597	54	42	4	9	11.9

TABLE III—Results of the backcross *Rg* Ts_1. *rg* ts_4 ×*rg* ts_4.

Pedigree Number	Parental Combinations		Recombinations		Percentage crossing over
	Rg Ts_4	rg ts_4	Rg ts_4	rg ts_4	
L598	135	148	1	4	1.7

TABLE IV—Results of the backcross *Rg A. rg a* × *rg a B Pl.*

Pedigree Number	Parental Combinations		Recombinations		Percentage crossing over
	Rg A	rg a	Rg a	rg A	
L592	76	49	51	56	46.1
L598	84	93	52	59	38.5
Totals	160	142	103	115	41.9

6. It appears probable from these relations that the two linkage groups, a_1—ts_4 and d_1—pg_2, which have been tentatively postulated heretofore are in reality one.

7. Additional evidence (unpublished) obtained at Cornell University by Emerson, Hofmevr and Miss McClintock, independently, and kindly put at our disposal by these workers, confirms the conclusion that a—ts_4 and d_1—pg_2 are in the same linkage group and provides the basis for an outline map of the chromosome.

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Guiding Mental Growth

THE GUIDANCE OF MENTAL GROWTH IN INFANT AND CHILD, *by* Arnold Gesell. Pp. XI+322. $2.25. The Macmillan Company, New York. 1930.

ORGANIZED mental hygiene as such, has developed during the past fifteen or twenty years, and in the last six years there has been a notable increase of interest in the mantal hygiene of young children. The general problem is concerned with a very complicated field in which there are great diversities of opinion and numerous methods of approach, and Dr. Gesell owing to his many years of close contact with child guidance organizations and developmental research problems should be particularly well fitted to write about the "preschool child."

The presentation has been divided into three parts: (1) The Progress of Guidance Concepts, (2) Problems and Methods of Child Guidance and (3) Science and the Protection of Child Growth. The first chapter gives a survey of the new trends and movements describing the rôles played by various governmental and philanthropical organizations, and emphasizing the stupendous proportions attained by the research program in the field of child development. This is followed by chapters containing accounts of the infant and parent relationships, the older concepts of child growth, and nursery school movements from the eighteenth century to the present time. Among the historical descriptions is an interesting story of the parental doctorines and practical methods of child training practiced by John Westley's mother, Susannah Westley, indicating that she was not one to "spare the rod." In one passage of her record she stated, "When turned a year old (and some before), they were taught to fear the rod, to cry softly; by which means they escaped abundance of correction they might otherwise have had; and that most odious noise of the crying of children was rarely heard in the house; but the family usually lived in as much quietness as if there had not been a child among them." This and similar passages offer remarkable contrasts between eighteenth and twentieth century child psychology, particularly in the parent-child relationship of the two periods. The early ideas of Bushnell appearing in his discourses on "Christian Nuture" are also well reviewed, and one chapter consists entirely of illustrations taken from old lithographs, engravings and photographs depicting different aspects of child life.

In part two are found the main physical and psychological aspects of the development of young children with emphasis on the growth processes, developmental defects, emotional constitutions, and on the modern methods

of preventing and correcting such deviations, as are amenable to therapeutic attempts.

Part three includes about twenty-five pages on "Heredity and Mental Growth" in addition to the medical, psychiatric and other aspects of infant behavior, but "no sundering distinction should be made between heredity and environment. The two interact conjointly. We need a correlating concept which will bring both sets of factors into intimate, reciprocal interplay. Growth is such a concept. It resolves the antithesis of endowment and environment in favor of a unifying dynamic outlook." . . . . "The term *growth* may be constructed to embrace the total complex of ontogenetic development. Maturation refers to those phases and products of growth which are wholly or chiefly due to innate and endogenous factors." Clinical, experimental and normative observations have produced evidences of behavior maturation in the development of prehension, in the developmental correspondence in identical twins, in the limitations of training, in the restricted influence of physical handicaps, and in developmental progression in emotional behavior.

Regarding heredity, the author states his position frankly:

> It is the hereditary ballast which conserves and stabilizes the growth of each individual infant. It is indigenous in its impulsion; but we may well be grateful for this degree of determinism. If it did not exist the infant would be a victim of a flaccid malleability which is sometimes romatically ascribed to him. His mind, his spirit, his personality would fall a ready prey to disease, to starvation, to malnutrition and worst of all, to misguided management. As it is, the inborn tendency toward optimum development is so inveterate that he benefits liberally from what is good in our practice and suffers less than he logically should from our unenlightenment. Only if we give respect to this inner core of inheritance can we respect the important individual differences which distinguish infants as well as men.

The results so far obtained in child study are beyond the synthesis of any group of experts, but there are hopeful indications and the program for procedures in this field is highly constructive from the modern viewpoint. The present book has done much toward assembling new material, giving practical scientific methods and data, and unifying various concepts in this vast array of problems, as well as having offered an interesting historical background to infant and child study.

N. D. C. Lewis.

A SHORT-TOED FAMILY

Brachydactyly in the Feet of Humans

RAY T. CUTTER and W. M. NELSON
University of Oregon

"SHORT-TOES" FROM THE OUTSIDE

Figure 14

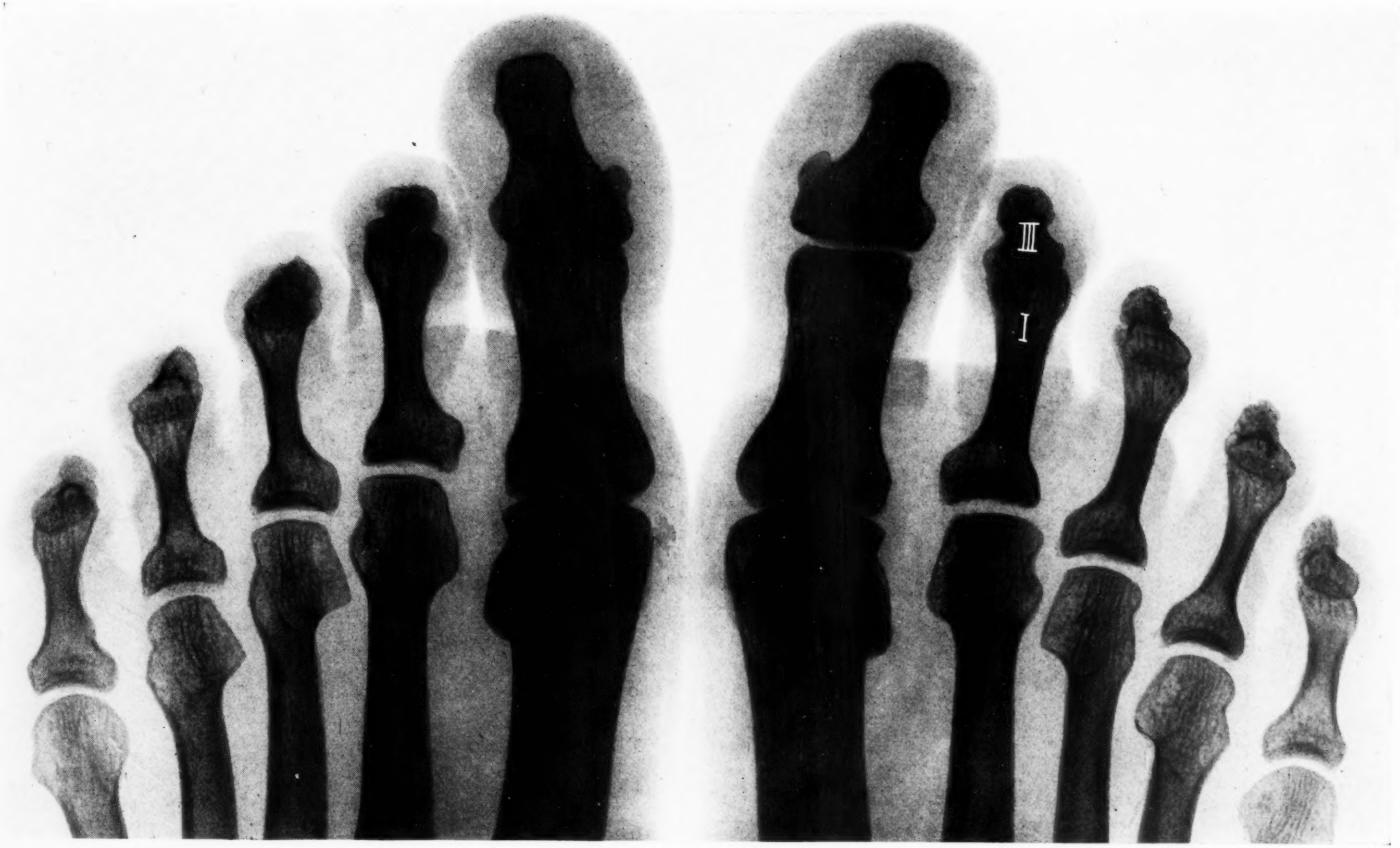
The absence of a joint is not very noticeable in the toes, but is more striking when it affects the fingers. This character varies in its manifestations; in some families only the toes are affected, in others only the fingers, and in others both fingeres and toes lack a joint.

BRACHYDACTYLY is a Mendelian trait that is occasionally found in humans. For a time it was known that Mendel's laws of heredity applied in plants, where Mendel discovered them, and later were observed to be in operation in animals, but it was not until somewhat later that it was definitely established that even human traits, at least some of them, were inherited according to Mendel's laws.

One of the first Mendelian traits found in humans was brachydactyly, although another Mendelian trait, the inheritance of eye color, is probably the one most commonly cited.

Brachydactyly may occur in the hands or the feet of an individual, or in both the hands and the feet of the same person. As far as we know it has never been known to occur in the hands of one generation, and then appear in the feet of the next generation, or *vice-versa.* In other words, brachydactyly of the hands is independent of brachydactyly of the feet, and brachydactyly of the feet is inherited regardless of whether or not the trait is present in the hands.

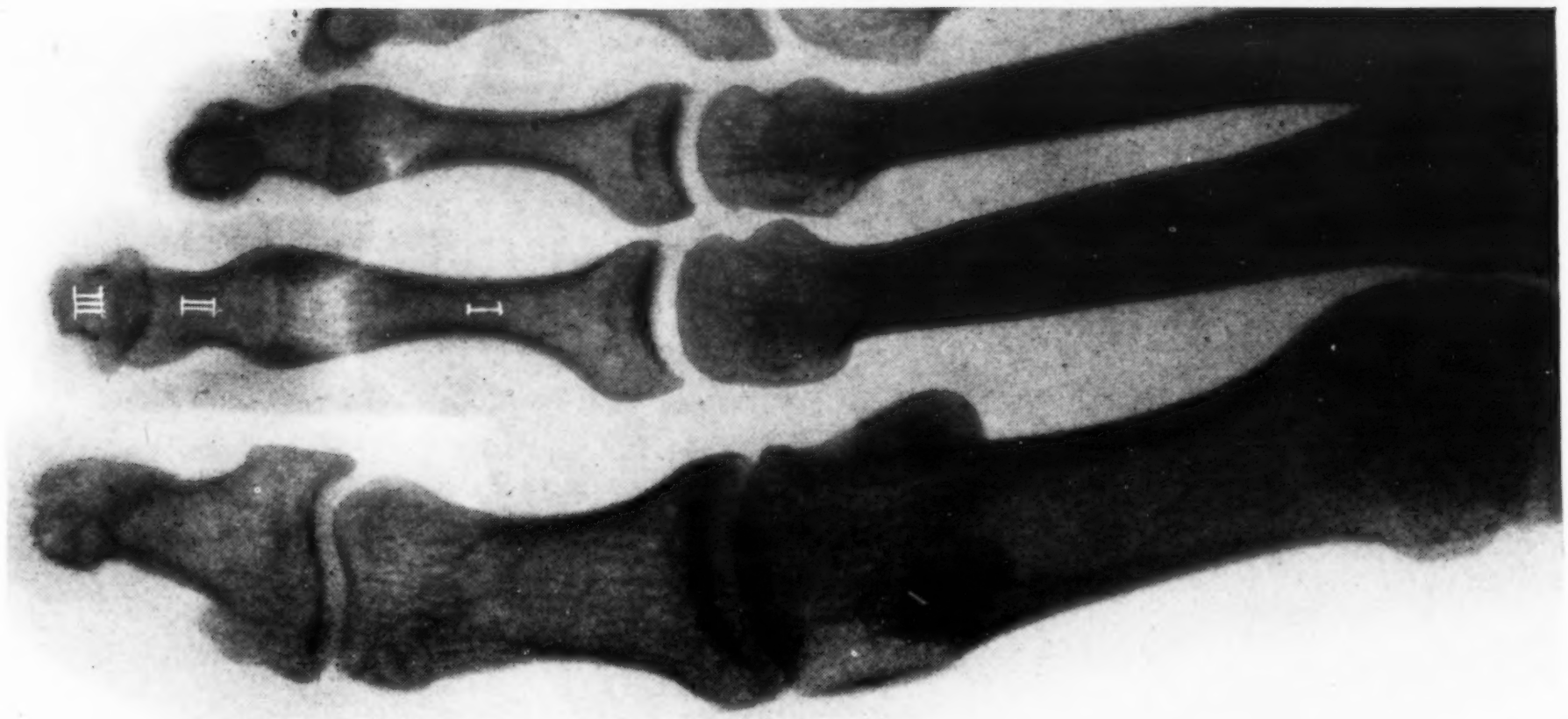
Brachydactyly is a compounded word meaning a shortening of the finger or toe. The shortening is caused by or is the result of the absence of one of the three bones or phalanges making up the finger or the toe, as the case may be. The fingers or toes affected are the small ones, the number of bones



A TOE-JOINT MISSING

Figure 15

This X-ray photograph shows that this individual lacks one of the phalanges of his toes, as can be seen by a comparison with the normal foot shown in Figure 15. Normally the big toe, like the thumb, has only two phalanges, so this peculiarity might be looked upon as being due to all the toes attempting to be big toes. While the innovation has increased their anatomical resemblance, perhaps, they still retain most of their other attributes.



NORMAL TOES

Figure 16

The three phalanges are numbered to facilitate comparison with the short toes in Figure 14. Note that phalange II is missing in the other picture.

in the thumb and large toe remaining the same as in a normal extremity.

Some students of this subject are inclined to substitute the word brachyphalangy for brachydactyly. But actually it is not the phalanx or phalange that is shortened, but it is the dactyl or whole digit that is shortened by the omission of a joint.

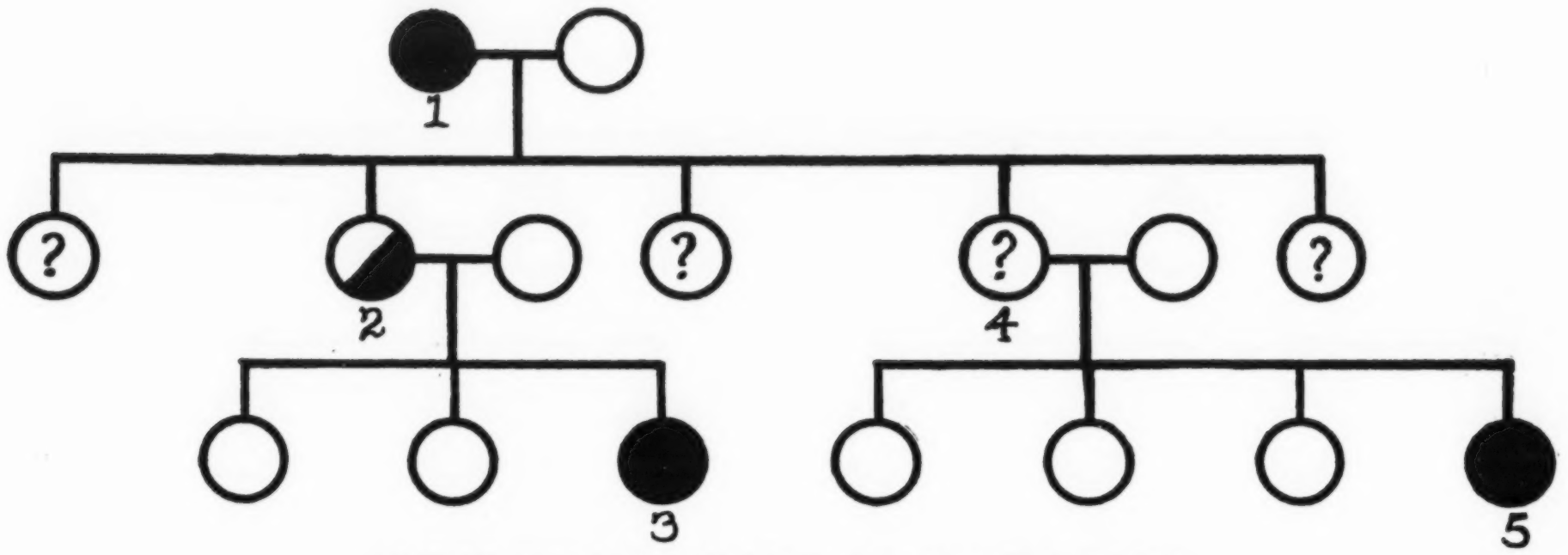
Accompanying this article are two radiographs, one of a normal foot and one of the brachydactylous feet. Since there are the same number of bones or phalanges in the normal hand as in the normal foot a comparison of your own hand with the radiographs will show you just what is meant by brachydactyly.

There are only two phalanges in the normal thumb or in the great toe, and you will note that this is also true of the brachydactylous foot. But while there are *three* phalanges in each of the fingers or small toes of a normal hand or foot, there are only two phalanges each in the small toes of the brachydactylous foot.

The interesting thing about this particular case of brachydactyly is that it is in the foot rather than in the hand, where it is customarily found. Although this trait may be present in the foot as often as in the hand, its appearance in the hand would be more readily noticed. The wearing of shoes would tend to conceal the trait and it would often pass unnoticed. Case number 3, on the accompanying family chart, was over twenty years old befor he noticed that his foot differed from a normal foot. Case 5, a girl, did not notice the abnormality until we called it to her attention.

Inasmuch as the character is inherited regardless of sex, male and female are not indicated on the family chart. It will be noticed that the chart is far from being complete, in that there are so many members in which it is not known whether the trait is present or not. It is very difficult, we found, to gather data of this kind. Many of the members of this family, unfortunately lacking the scientific viewpoint, refused to reveal whether or not they manifested this interesting trait.

Other members, fearing that the character might be a mark of degeneracy, might have been said to have gone out of their way to avoid know-



INHERITANCE CHART OF SHORT TOES

Figure 17

The trait appears in both sexes. Case 2 has the normal number of phalanges but they are much shortened. Case 4 would not permit examination, but would be expected to show the trait.

ing whether they carried the trait, and of course gave the investigators no satisfaction. Then too, the family was scattered so widely that it was not possible to approach or to examine every member.

Of the forty living descendants of the original couple, only four (excluding Case 2, which will be referred to later) are known to have inherited the trait. Nine are known not to possess the trait, and the remaining twenty-eight are in doubt. The chart does not show all the descendants. The families of this group are large and if all the data could be obtained it would no doubt throw considerable light on the subject.

All the cases of brachydactyly on record seem to show that the character is a Mendelian dominant. That is, the trait is present in each generation, and usually in about 50 per cent of the progeny of a brachydactylous parent mated with a normal. There is not enough evidence in this particular case to bear out that point.

In case number 2, the father of a very evident case of brachydactyly (number 3 on the chart), the normal number of bones or phalanges are present but they are abnormally short, showing that in at least one individual of that generation the trait had manifitself in a quite different way from what was to be expected, especially in an individual who transmitted the trait to the next generation.

Case number 4 (the mother of case 5), although yet undetermined, would no doubt show the trait if an examination were made.

Quoting from Applied Eugenics, by Popenoe and Johnson: "One of the best attested single characters in human heredity is brachydactyly, 'short-fingerness,' which results in a reduction in the length of the fingers by the dropping out of one joint." And again: "Brachydactyly, apparently a dominant. This is so much cited in text-books on Mendelism that the student might think it is a common character. As a fact, it is extremely rare, being found in only a few families. . . . . "Traits like these, which are easily defined and occur very rarely, make up a large part of the cases of probably Mendelian heredity. They are little more than curiosities, their rarity and abnormal nature depriving them of evolutionary significance other than to demonstrate that Mendelian heredity does operate in man."

For a further study of brachydactyly the reader is referred to a previous issue of the JOURNAL OF HEREDITY,* where will be found two articles on brachydactyly of the hand.

*Vol. 15, pp. 323-334